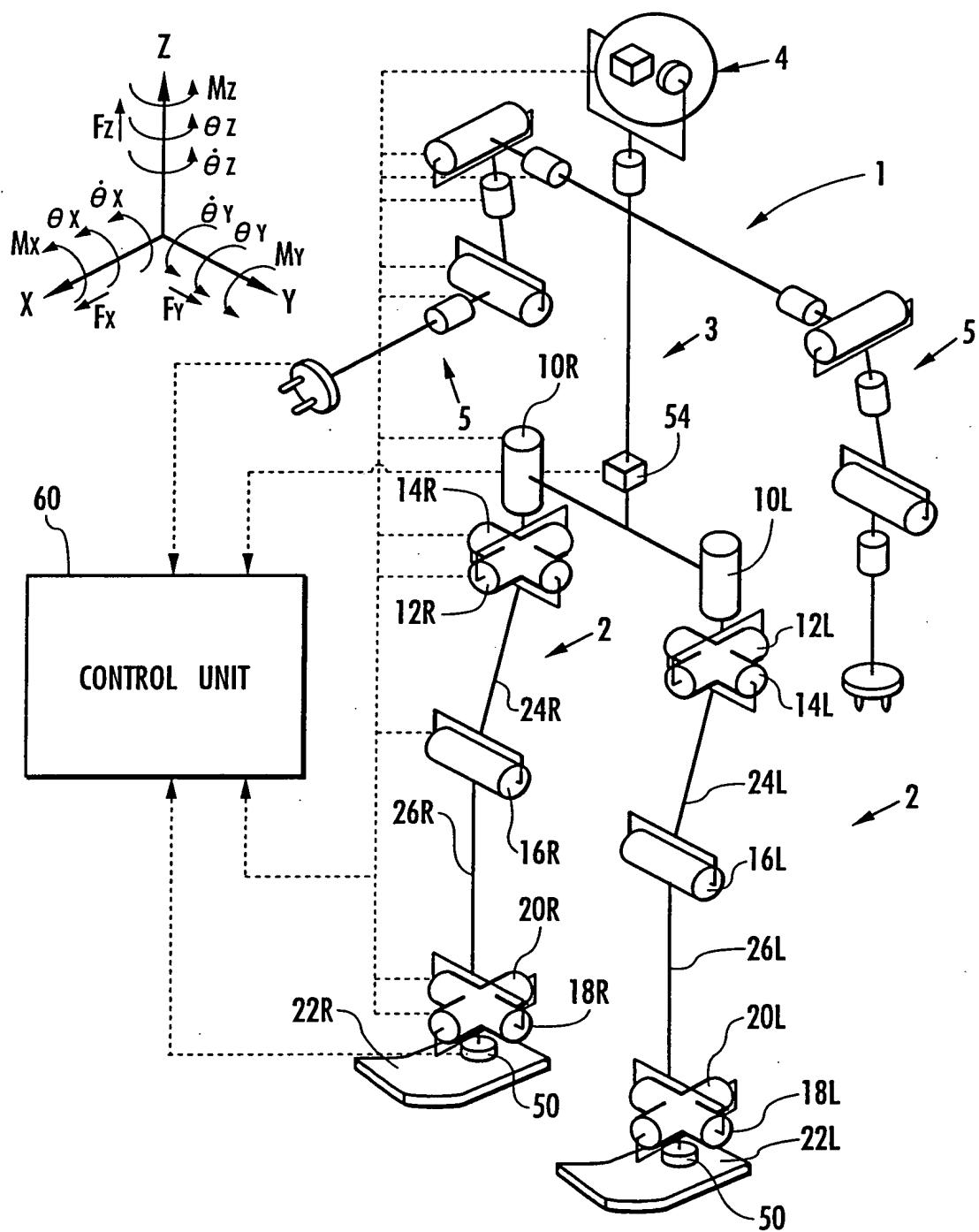


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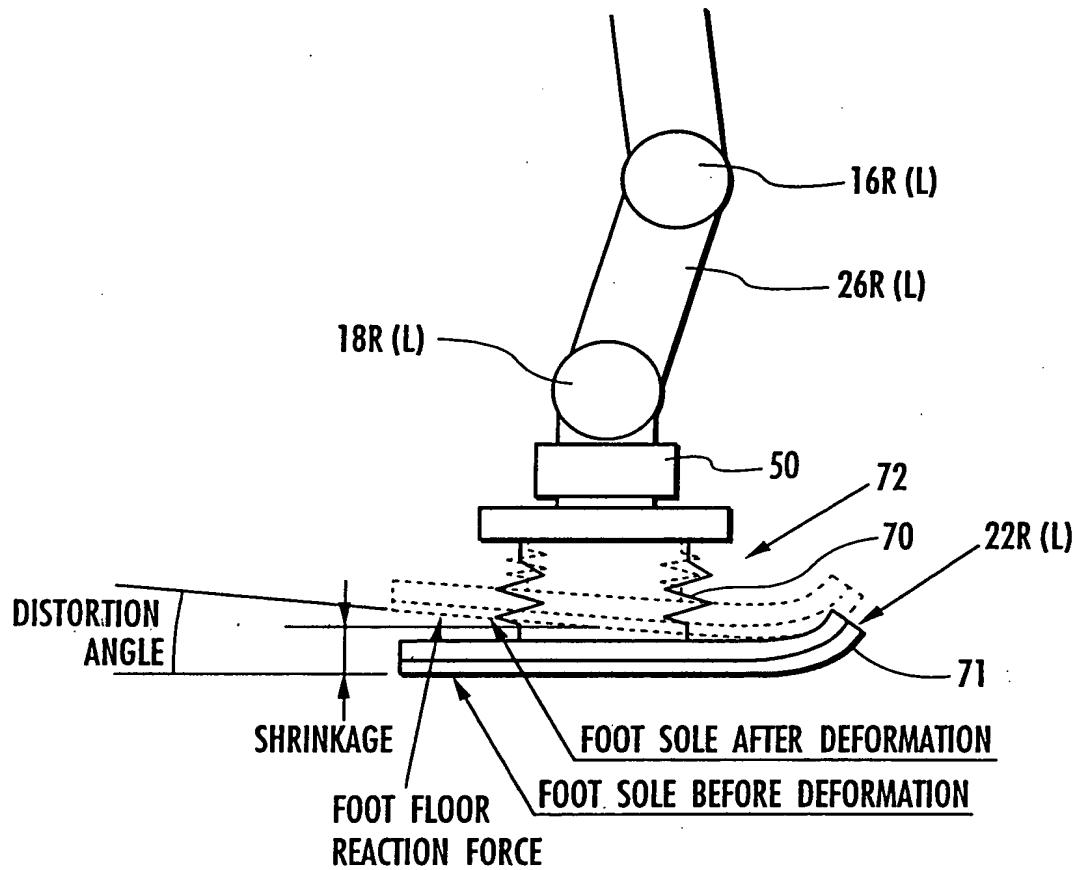
FIG. 1



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FIG. 2



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FIG. 3

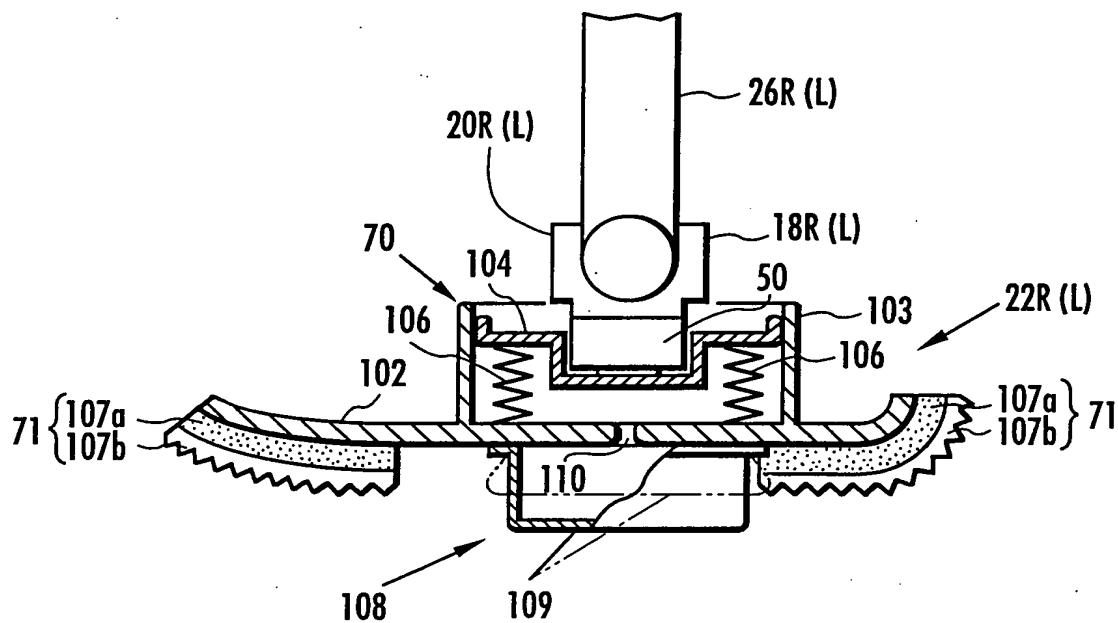
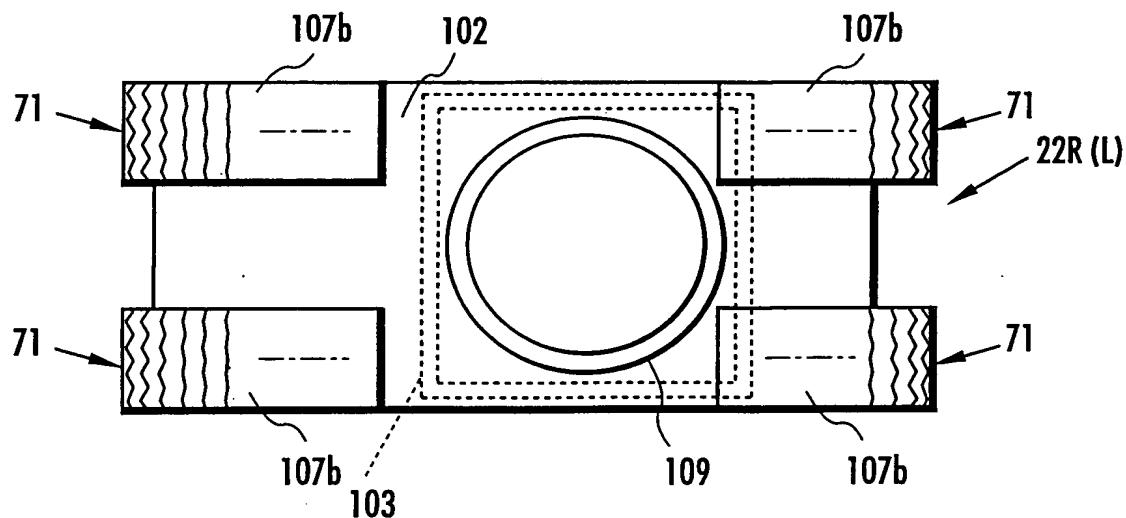


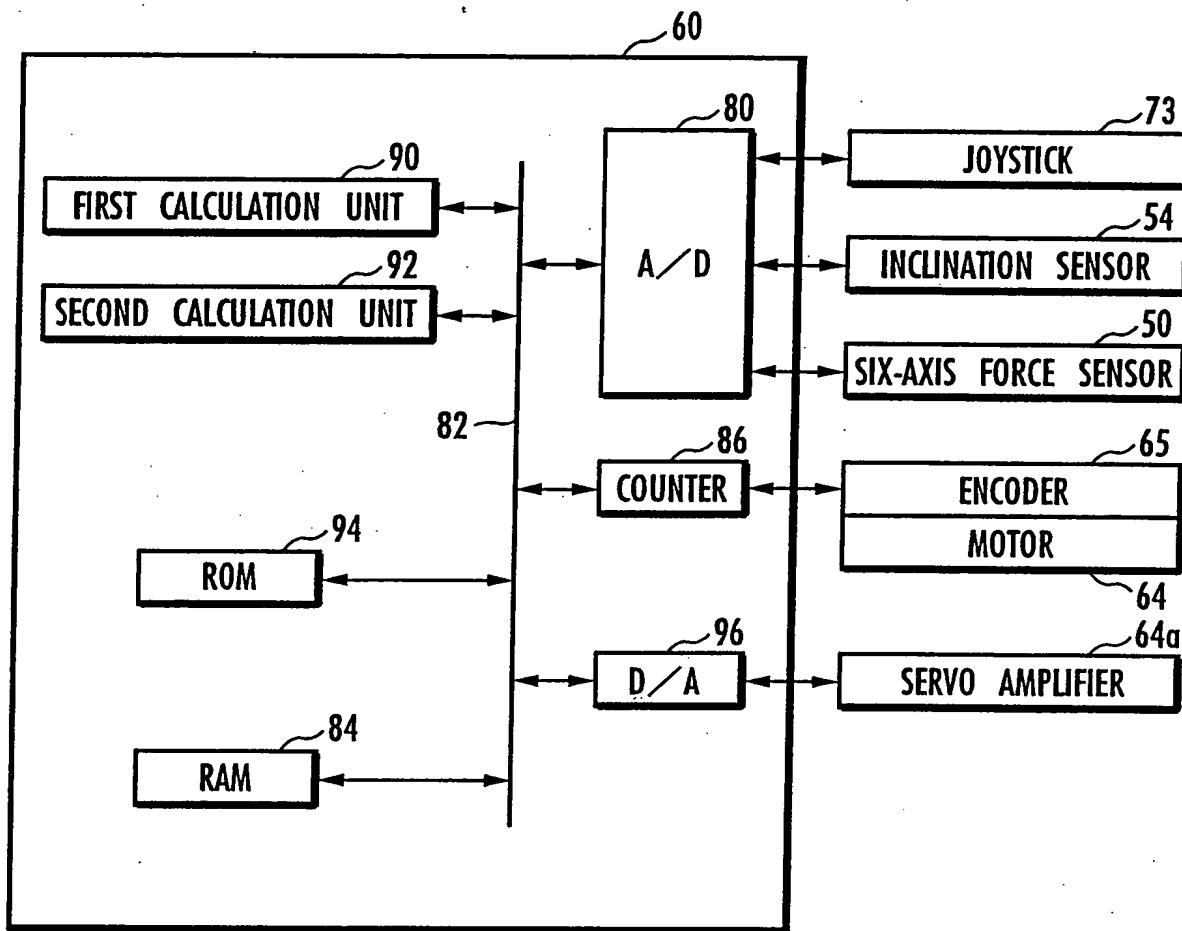
FIG. 4



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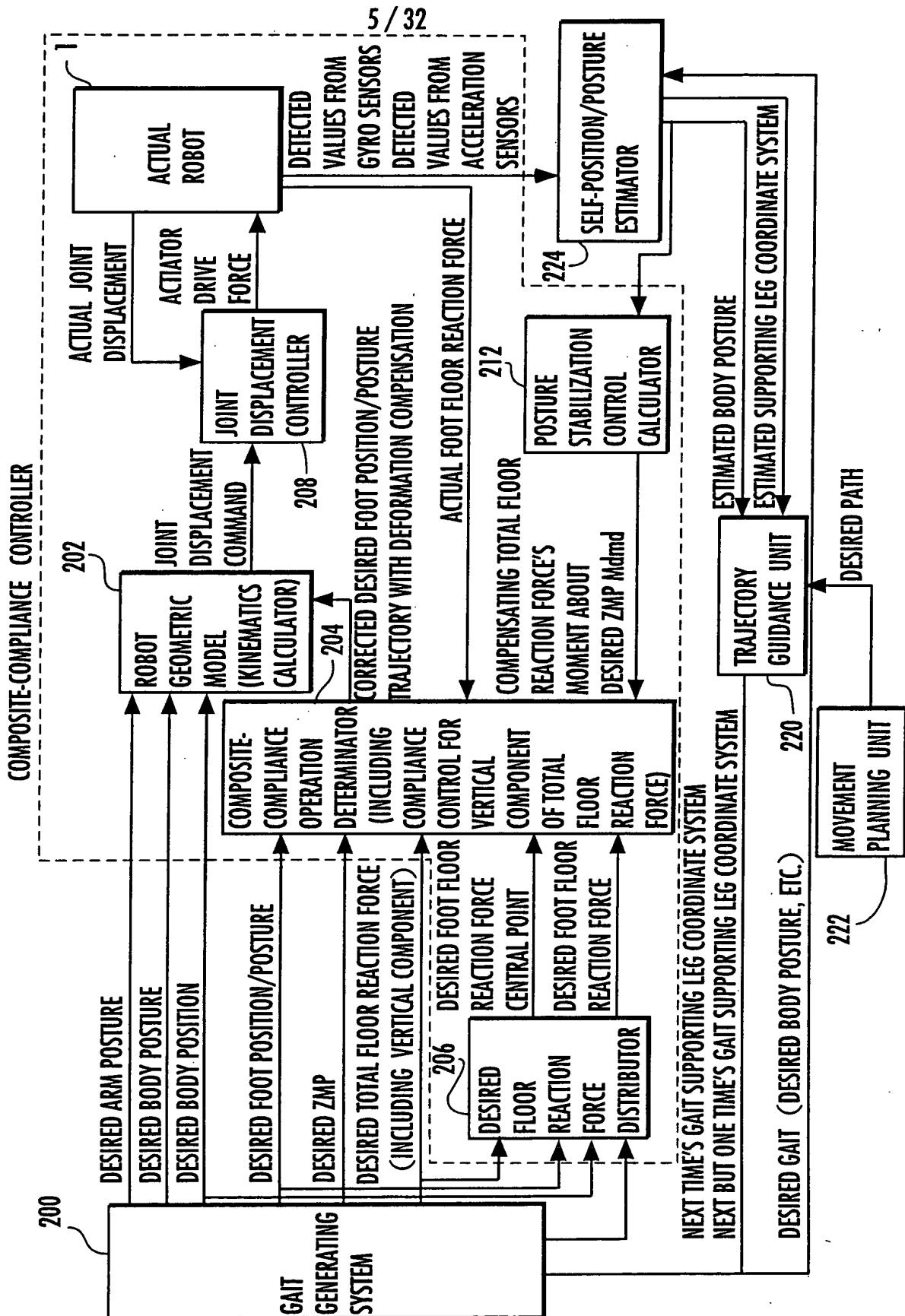
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FIG. 5



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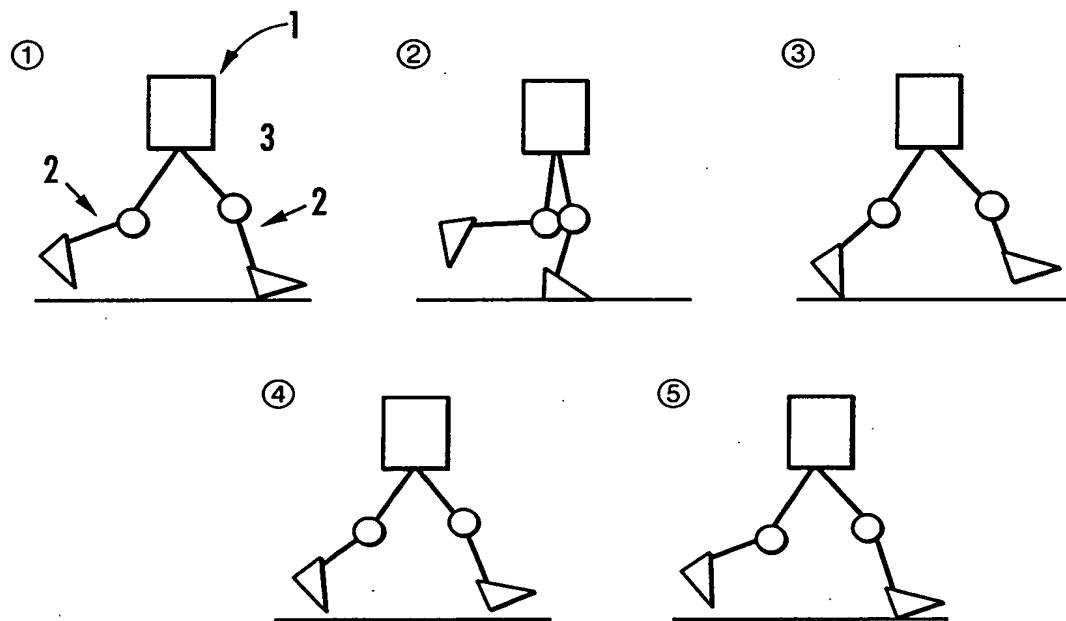
FIG. 6



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FIG. 7



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FIG. 8 (a)

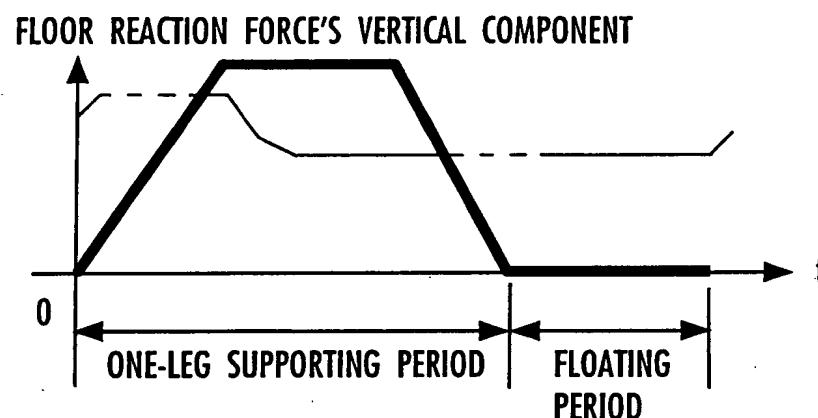
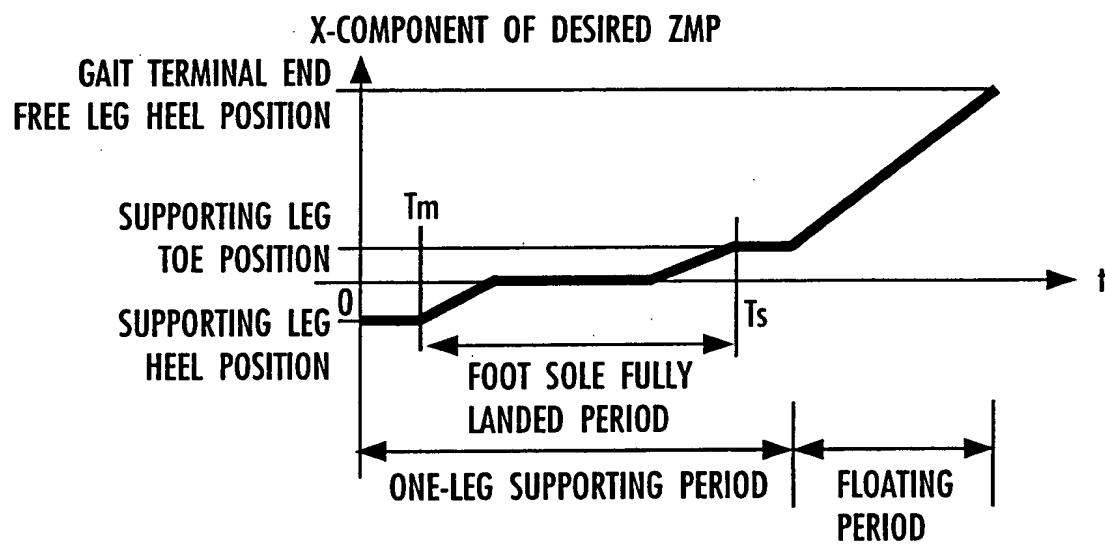


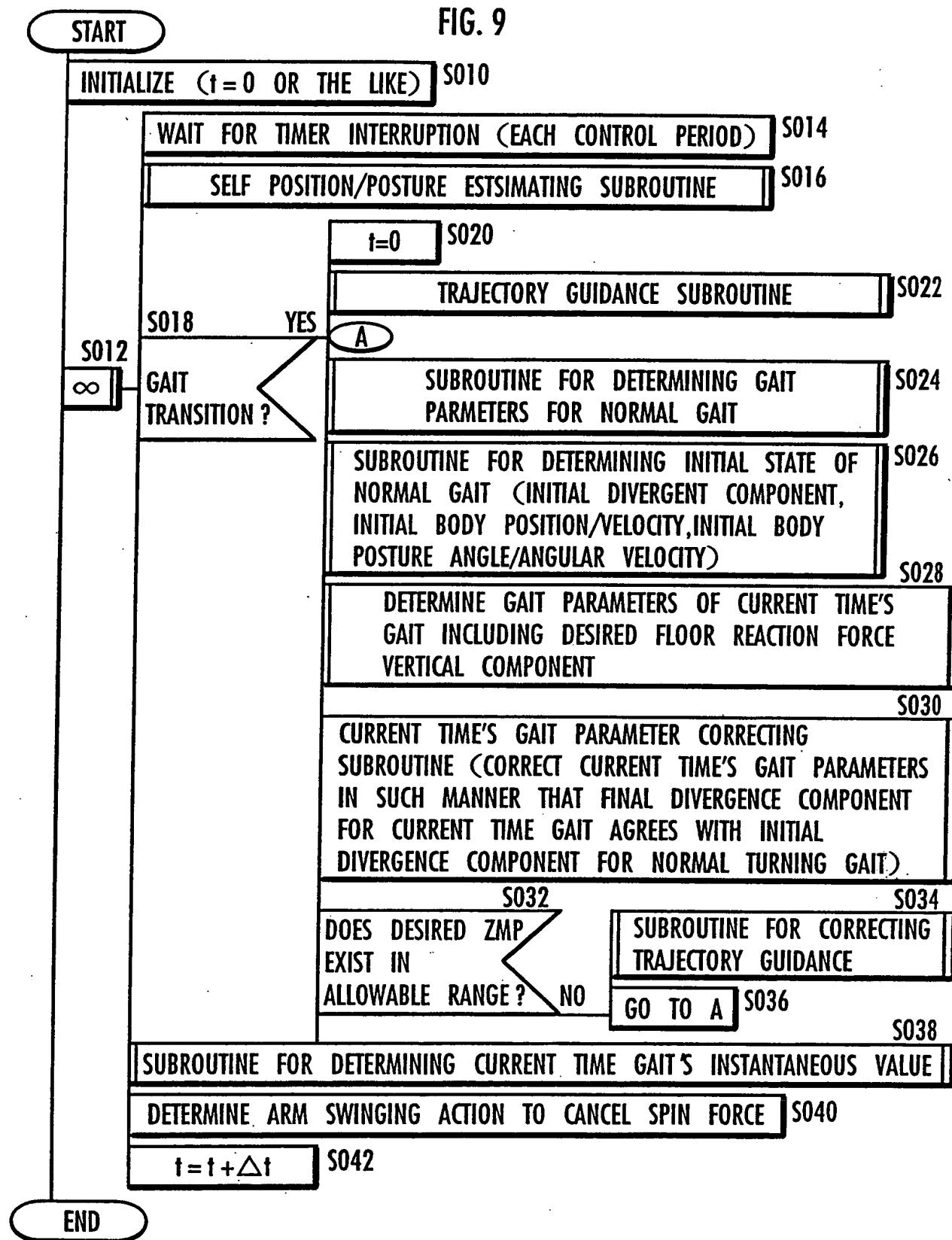
FIG. 8 (b)



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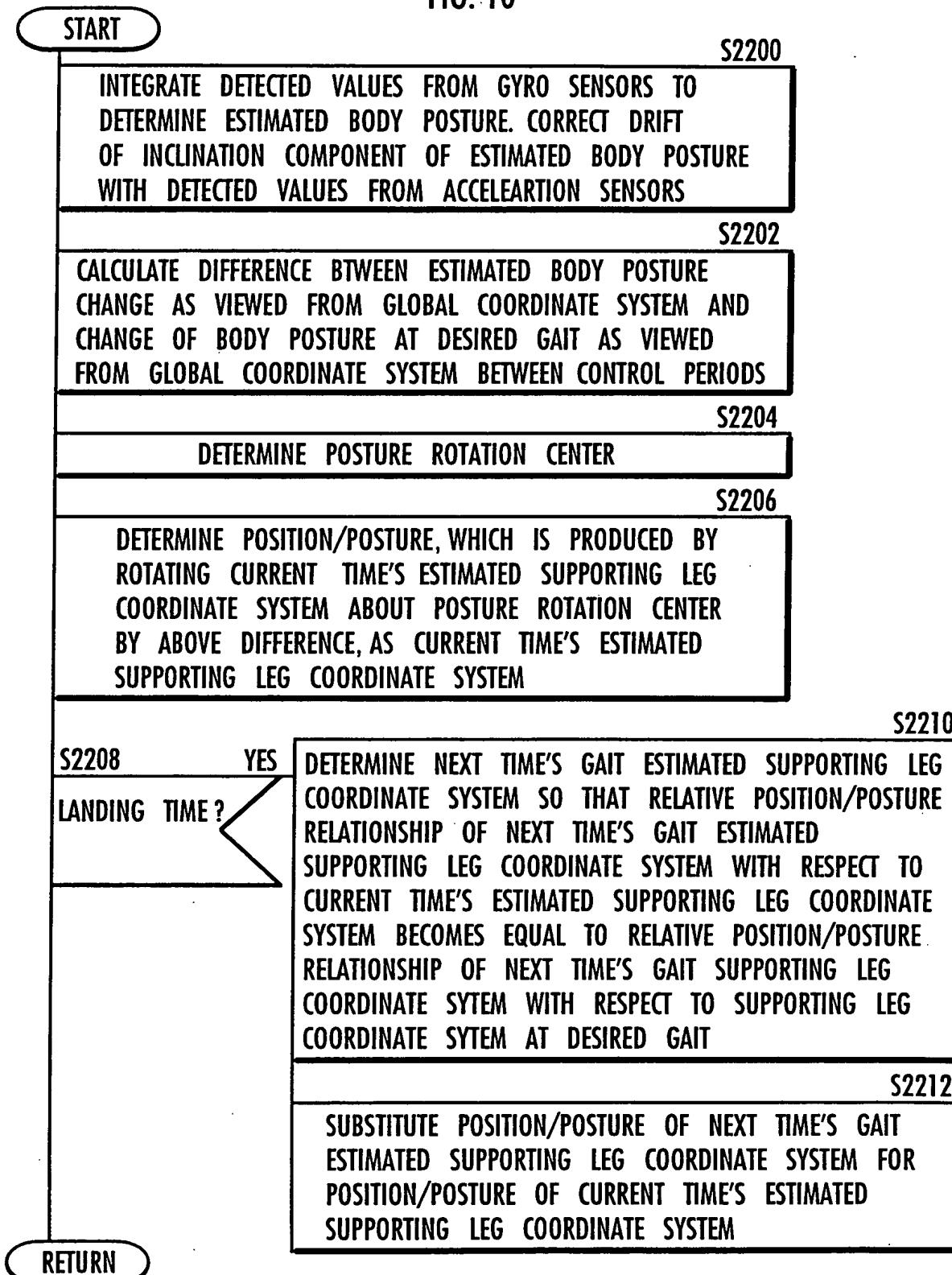
FIG. 9



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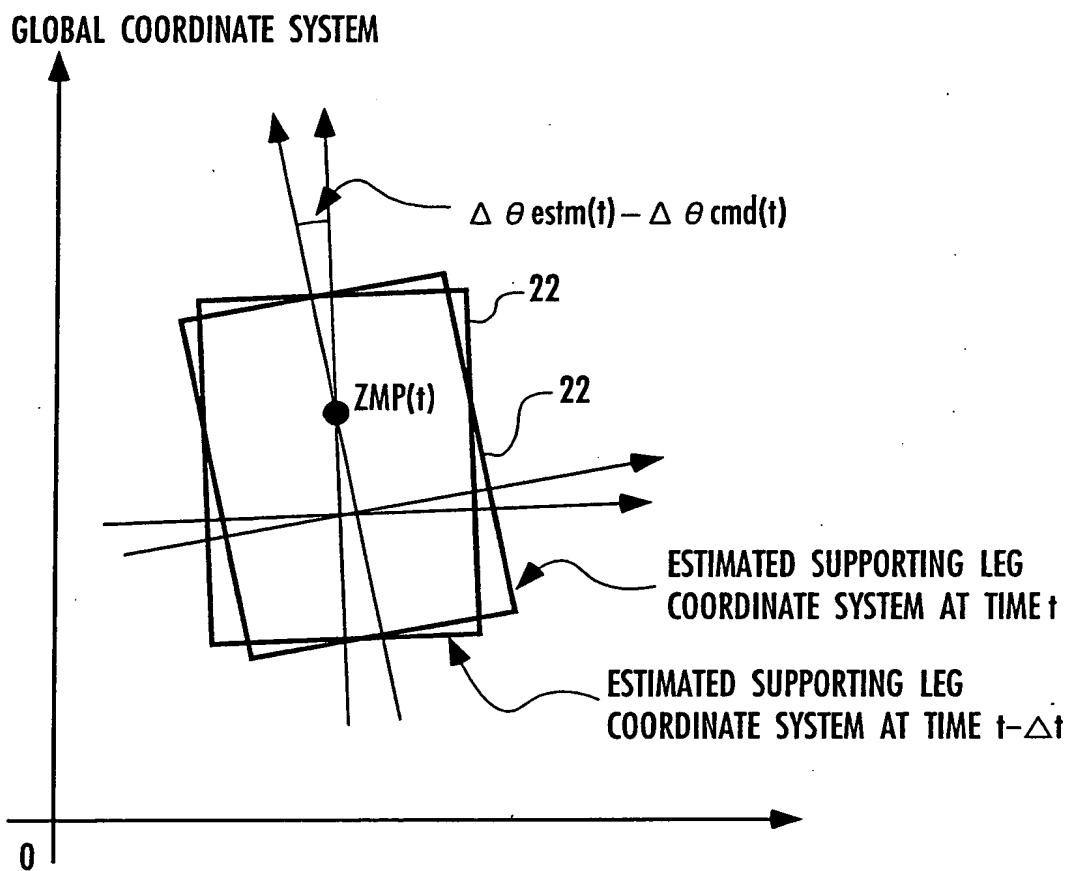
## FIG. 10



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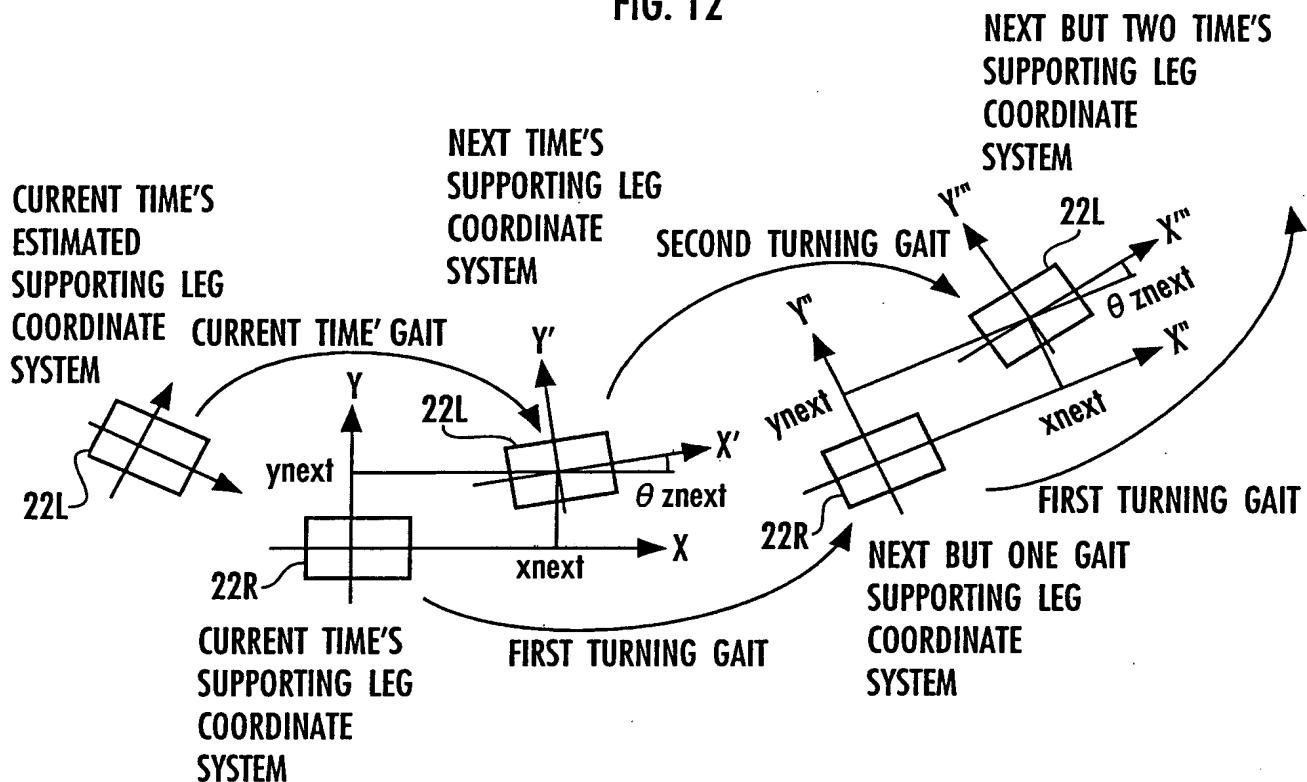
FIG. 11



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FIG. 12



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## FIG. 13

ENTRY

S3000

DETERMINE CURRENT TIME'S SHORT-TERM DESIRED POINT Q(0) BASED ON REPRESENTATIVE POINT P(0) OF ESTIMATED SUPPORTING LEG COORDINATE SYSTEM AND DESIRED PATH

S3002

DETERMINE REPRESENTATIVE CANDIDATE POINT R(0) OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM ON LINE SEGMENT P(0) Q(0)

S3004

DETERMINE POINT CLOSEST TO REPRESENTATIVE CANDIDATE POINT R(0) IN ALLOWABLE LANDING RANGE (SELF-DEPENDENT ALLOWABLE LANDING POSITION RANGE) , AS P(1)

S3006

DETERMINE POSITION AND ORIENTATION OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM SO THAT POSITION OF REPRESENTATIVE POINT OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS P(1) AND DIRECTION OF X-AXIS OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS ORIENTATION OF LINE SEGMENT P(0)Q(0)

S3008

DETERMINE NEXT TIME'S SHORT-TERM DESIRED POINT Q(1) BASED ON REPRESENTATIVE POINT P(1) OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM AND DESIRED PATH

S3010

DETERMINE REPRESENTATIVE CANDIDATE POINT R(1) OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM ON LINE SEGMENT P(1) Q(1)

S3012

DETERMINE POINT CLOSEST TO REPRESENTATIVE CANDIDATE POINT R(1) IN ALLOWABLE LANDING RANGE (SELF-DEPENDENT ALLOWABLE LANDING POSITION RANGE) , AS P(2)

S3014

DETERMINE POSITION AND ORIENTATION OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM SO THAT POSITION OF REPRESENTATIVE POINT OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS P(2) AND DIRECTION OF X-AXIS OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS ORIENTATION OF LINE SEGMENT P(1) Q(1)

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FIG. 14

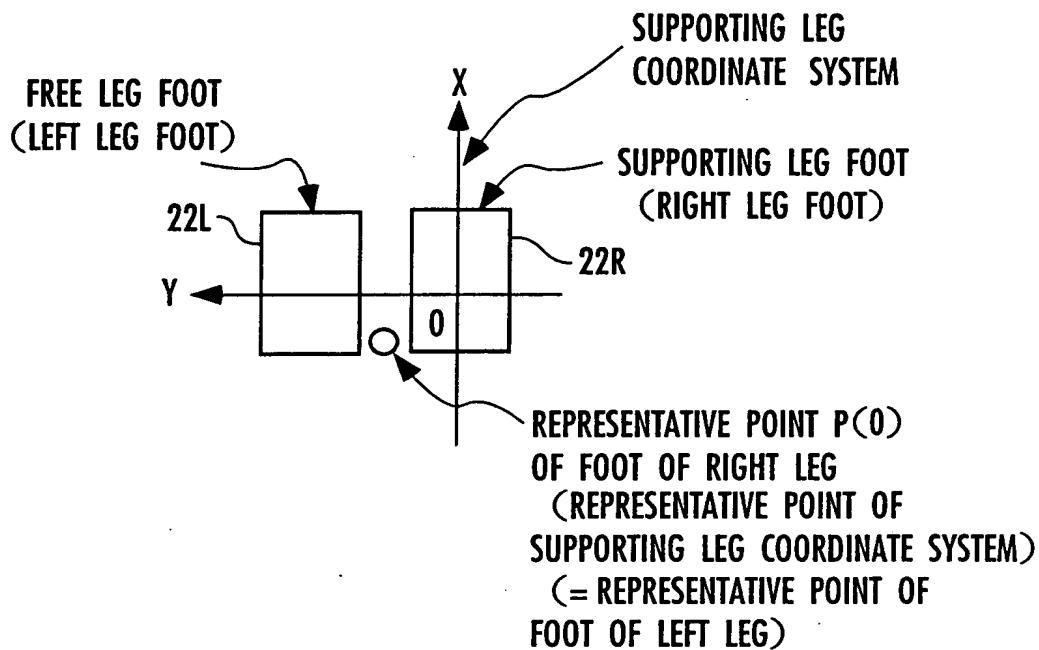
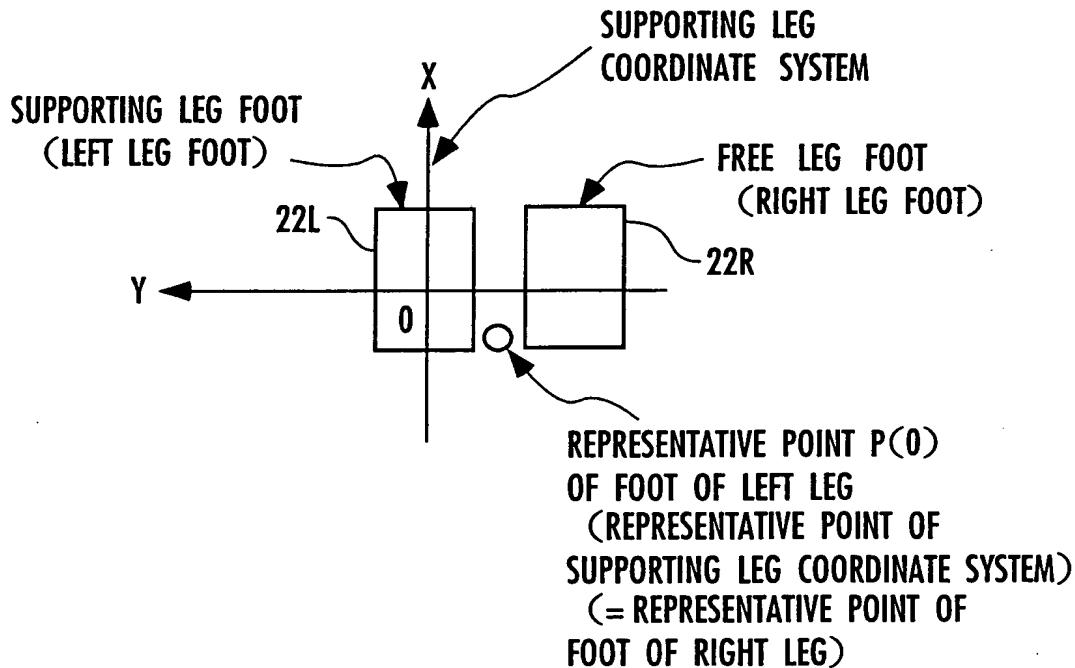


FIG. 15



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FIG. 16

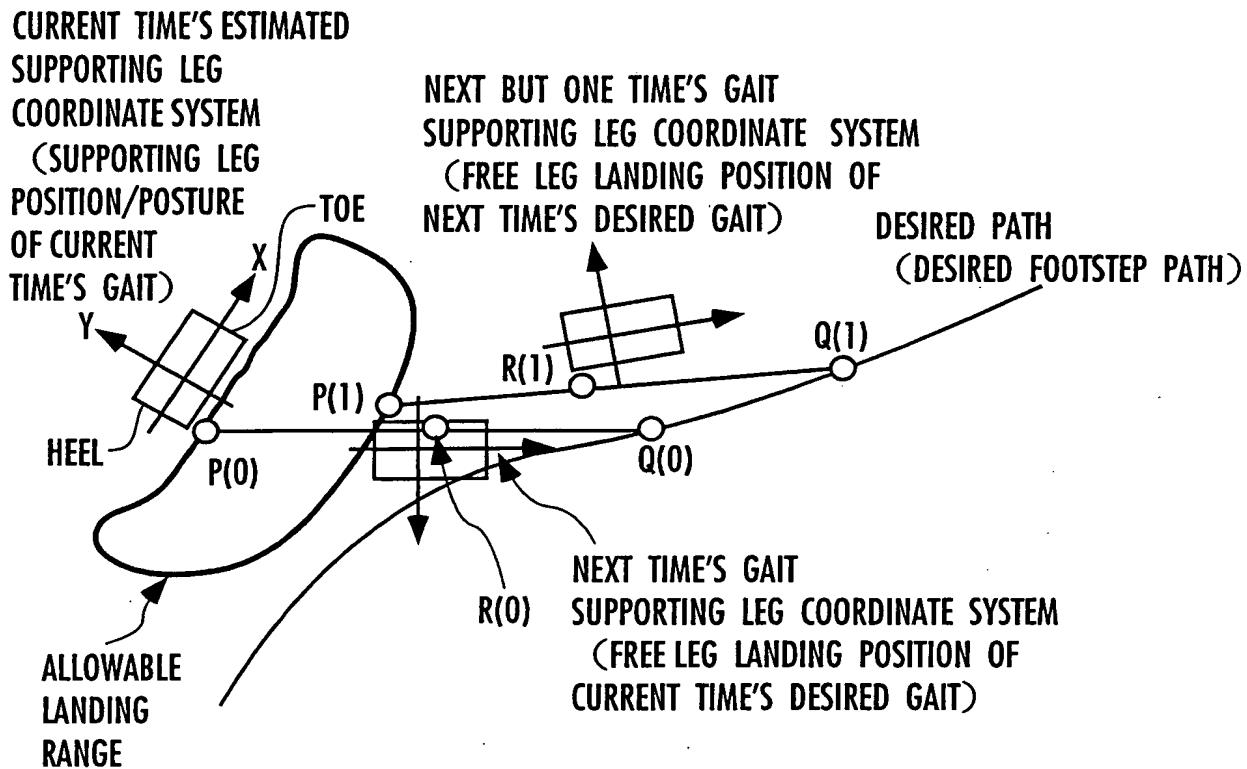
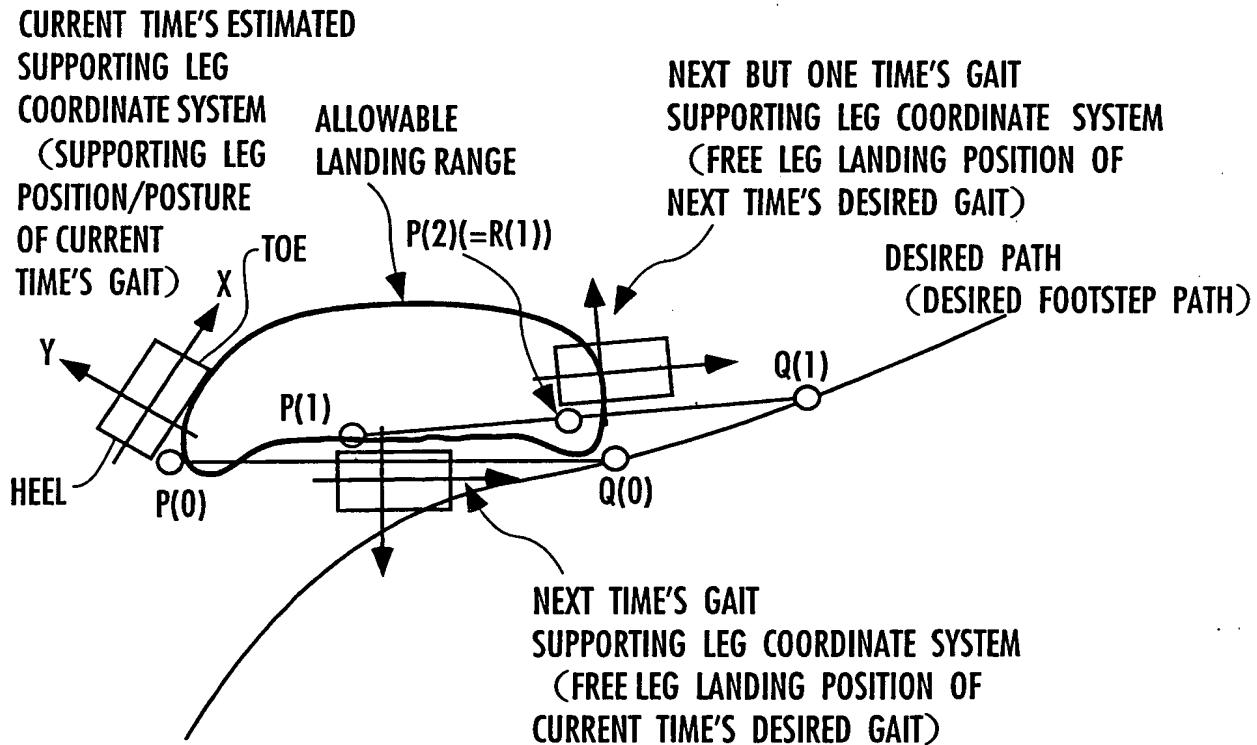


FIG. 17



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FIG. 18

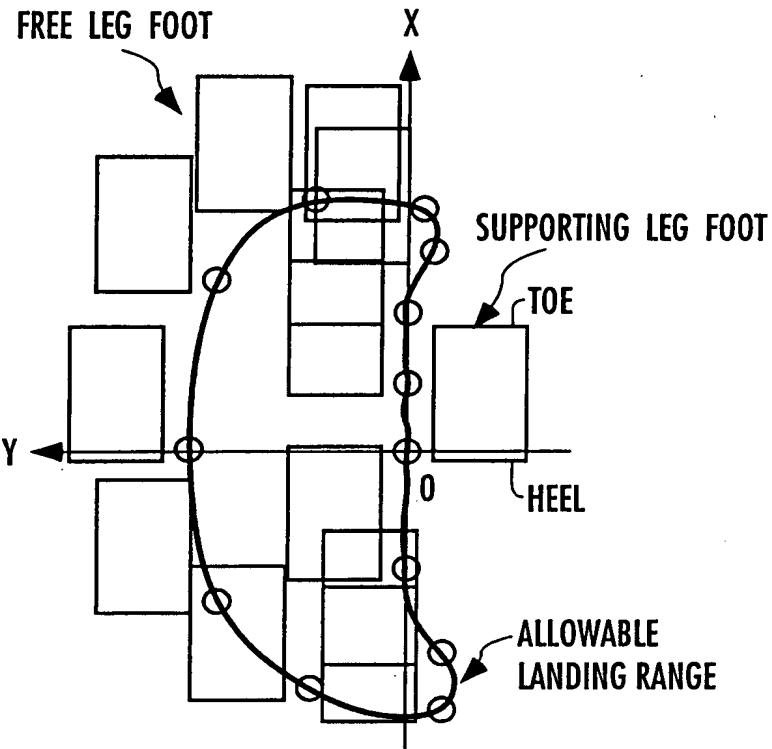
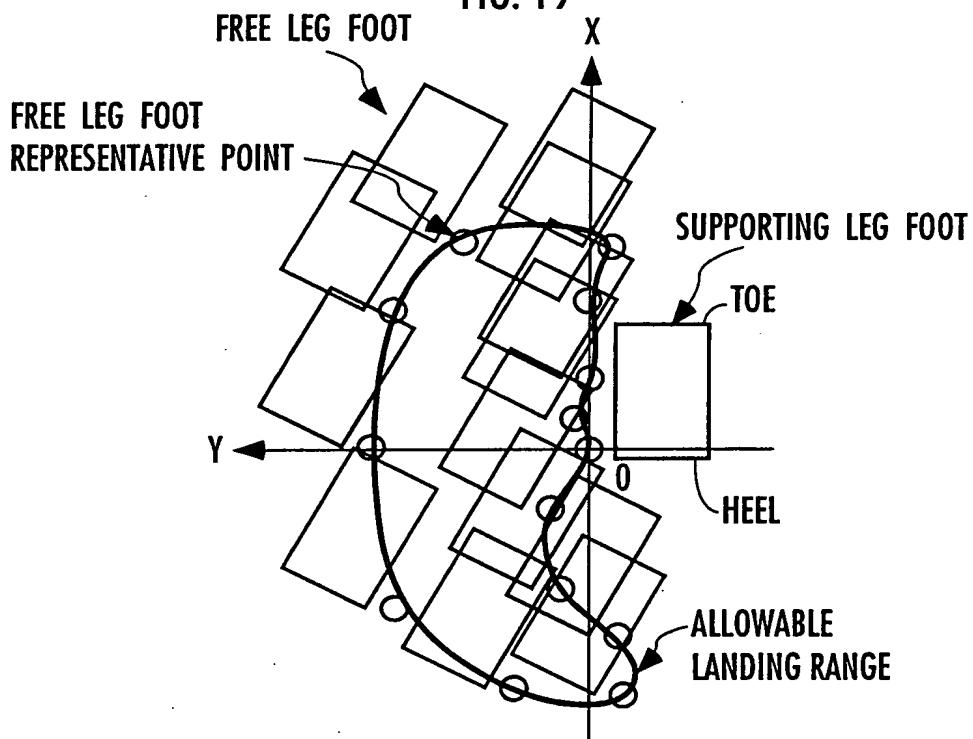


FIG. 19



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## FIG. 20

ENTRY

S3100

DETERMINE DEVIATION  $e$  BY WHICH DESIRED ZMP EXCEEDS ALLOWABLE RANGE

S3102

$$R(0) = K_a * e + R(0)$$

S3104

DETERMINE POINT CLOSEST TO REPRESENTATIVE CANDIDATE POINT  $R(0)$  IN ALLOWABLE LANDING RANGE (SELF-DEPENDENT ALLOWABLE LANDING POSITION RANGE), AS  $P(1)$ 

S3106

DETERMINE POSITION AND ORIENTATION OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM SO THAT POSITION OF REPRESENTATIVE POINT OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS  $P(1)$  AND DIRECTION OF X-AXIS OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS ORIENTATION OF LINE SEGMENT  $P(0)Q(0)$ 

S3108

DETERMINE NEXT TIME'S SHORT-TERM DESIRED POINT  $Q(1)$  BASED ON REPRESENTATIVE POINT  $P(1)$  OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM AND DESIRED PATH

S3110

DETERMINE REPRESENTATIVE CANDIDATE POINT  $R(1)$  OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM ON LINE SEGMENT  $P(1)Q(1)$ 

S3112

DETERMINE POINT CLOSEST TO REPRESENTATIVE CANDIDATE POINT  $R(1)$  IN ALLOWABLE LANDING RANGE (SELF-DEPENDENT ALLOWABLE LANDING POSITION RANGE), AS  $P(2)$ 

S3114

DETERMINE POSITION AND ORIENTATION OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM SO THAT POSITION OF REPRESENTATIVE POINT OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS  $P(2)$  AND DIRECTION OF X-AXIS OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS ORIENTATION OF LINE SEGMENT  $P(1)Q(1)$ 

RETURN

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## FIG. 21

ENTRY

S3200

DETERMINE CURVE THAT IS ASYMPTOTICALLY CLOSE TO DESIRED PATH BASED ON REPRESENTATIVE POINT  $P(0)$  OF ESTIMATED SUPPORTING LEG COORDINATE SYSTEM AND DESIRED PATH

S3202

DETERMINE REPRESENTATIVE CANDIDATE POINT  $R(0)$  OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM ON CURVE

S3204

DETERMINE POINT CLOSEST TO REPRESENTATIVE CANDIDATE POINT  $R(0)$  IN ALLOWABLE LANDING RANGE (SELF-DEPENDENT ALLOWABLE LANDING POSITION RANGE), AS  $P(1)$

S3206

DETERMINE POSITION AND ORIENTATION OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM SO THAT POSITION OF REPRESENTATIVE POINT OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS  $P(1)$  AND DIRECTION OF X-AXIS OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS ORIENTATION OF LINE TANGENTIAL TO CURVE AT REPRESENTATIVE POINT  $P(1)$

S3208

DETERMINE REPRESENTATIVE CANDIDATE POINT  $R(1)$  OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM ON CURVE

S3210

DETERMINE POINT CLOSEST TO REPRESENTATIVE CANDIDATE POINT  $R(1)$  IN ALLOWABLE LANDING RANGE (SELF-DEPENDENT ALLOWABLE LANDING POSITION RANGE), AS  $P(2)$

S3212

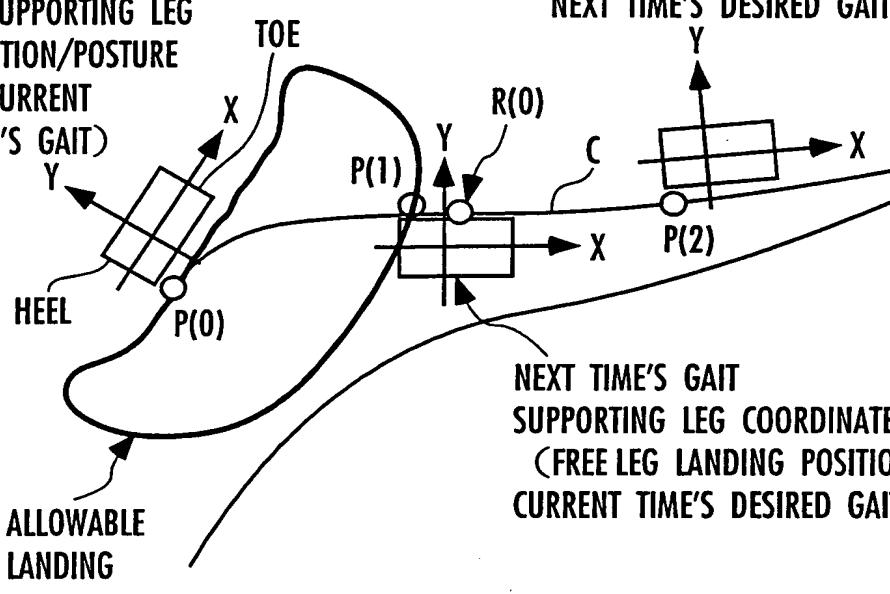
DETERMINE POSITION AND ORIENTATION OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM SO THAT POSITION OF REPRESENTATIVE POINT OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS  $P(2)$  AND DIRECTION OF X-AXIS OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS ORIENTATION OF LINE TANGENTIAL TO CURVE AT REPRESENTATIVE POINT  $P(2)$

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FIG. 22

CURRENT TIME'S ESTIMATED  
SUPPORTING LEG  
COORDINATE SYSTEM  
(SUPPORTING LEG  
POSITION/POSTURE  
OF CURRENT  
TIME'S GAIT)



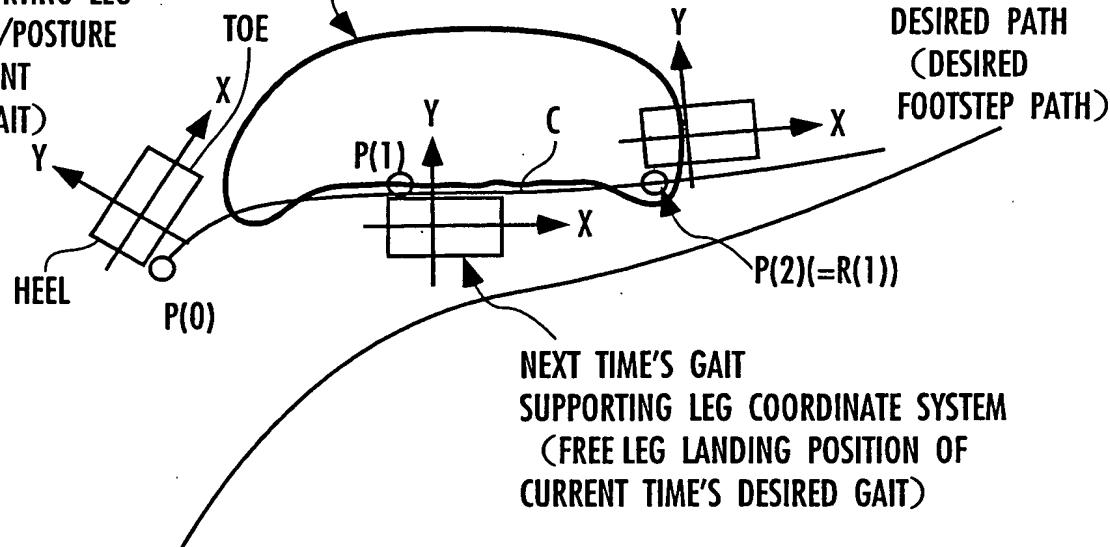
NEXT BUT ONE TIME'S GAIT  
SUPPORTING LEG COORDINATE SYSTEM  
(FREE LEG LANDING POSITION OF  
NEXT TIME'S DESIRED GAIT)

DESIRED PATH  
(DESIRED  
FOOTSTEP PATH)

NEXT TIME'S GAIT  
SUPPORTING LEG COORDINATE SYSTEM  
(FREE LEG LANDING POSITION OF  
CURRENT TIME'S DESIRED GAIT)

CURRENT TIME'S ESTIMATED  
SUPPORTING LEG  
COORDINATE SYSTEM  
(SUPPORTING LEG  
POSITION/POSTURE  
OF CURRENT  
TIME'S GAIT)

ALLOWABLE  
LANDING  
RANGE



NEXT BUT ONE TIME'S GAIT  
SUPPORTING LEG COORDINATE SYSTEM  
(FREE LEG LANDING POSITION OF  
NEXT TIME'S DESIRED GAIT)

DESIRED PATH  
(DESIRED  
FOOTSTEP PATH)

NEXT TIME'S GAIT  
SUPPORTING LEG COORDINATE SYSTEM  
(FREE LEG LANDING POSITION OF  
CURRENT TIME'S DESIRED GAIT)

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FIG. 24

## ENTRY

**S3300**

DETERMINE DEVIATION  $e$  BY WHICH DESIRED ZMP EXCEEDS ALLOWABLE RANGE

S3302

$$R(0) = K_0 * e + R(0)$$

S3304

DETERMINE POINT CLOSEST TO REPRESENTATIVE CANDIDATE POINT R(0) IN ALLOWABLE LANDING RANGE (SELF-DEPENDENT ALLOWABLE LANDING POSITION RANGE) AS P(1)

S3306

DETERMINE POSITION AND ORIENTATION OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM SO THAT POSITION OF REPRESENTATIVE POINT OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS  $P(1)$  AND DIRECTION OF X-AXIS OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS ORIENTATION OF LINE TANGENTIAL TO CURVE AT REPRESENTATIVE POINT  $P(1)$

53308

DETERMINE REPRESENTATIVE CANDIDATE POINT R(1) OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM ON CURVE

**S3110**

DETERMINE POINT CLOSEST TO REPRESENTATIVE CANDIDATE POINT R(1) IN ALLOWABLE LANDING RANGE (SELF-DEPENDENT ALLOWABLE LANDING POSITION RANGE) , AS P(2)

S3312

DETERMINE POSITION AND ORIENTATION OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM SO THAT POSITION OF REPRESENTATIVE POINT OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS  $P(2)$  AND DIRECTION OF X-AXIS OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS ORIENTATION OF LINE TANGENTIAL TO CURVE AT REPRESENTATIVE POINT  $P(2)$

**RETURN**

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## FIG. 25

ENTRY

S3400

DETERMINE CURRENT TIME'S SHORT-TERM DESIRED POINT Q(0) BASED ON REPRESENTATIVE POINT P(0) OF ESTIMATED SUPPORTING LEG COORDINATE SYSTEM AND DESIRED PATH

S3402

DETERMINE REPRESENTATIVE POINT P(1) OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM ON LINE SEGMENT P(0)Q(0) SO AS NOT TO EXCEED ALLOWABLE LANDING RANGE (SELF-DEPENDENT ALLOWABLE LANDING POSITION RANGE)

S3404

DETERMINE POSITION AND ORIENTATION OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM SO THAT POSITION OF REPRESENTATIVE POINT OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS P(1) AND DIRECTION OF X-AXIS OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS ORIENTATION OF LINE SEGMENT P(0)Q(0)

S3406

DETERMINE NEXT TIME'S SHORT-TERM DESIRED POINT Q(1) BASED ON REPRESENTATIVE POINT P(1) OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM AND DESIRED PATH

S3408

DETERMINE REPRESENTATIVE POINT P(2) OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM ON LINE SEGMENT P(1)Q(1) SO AS NOT TO EXCEED ALLOWABLE LANDING RANGE (SELF-DEPENDENT ALLOWABLE LANDING POSITION RANGE)

S3410

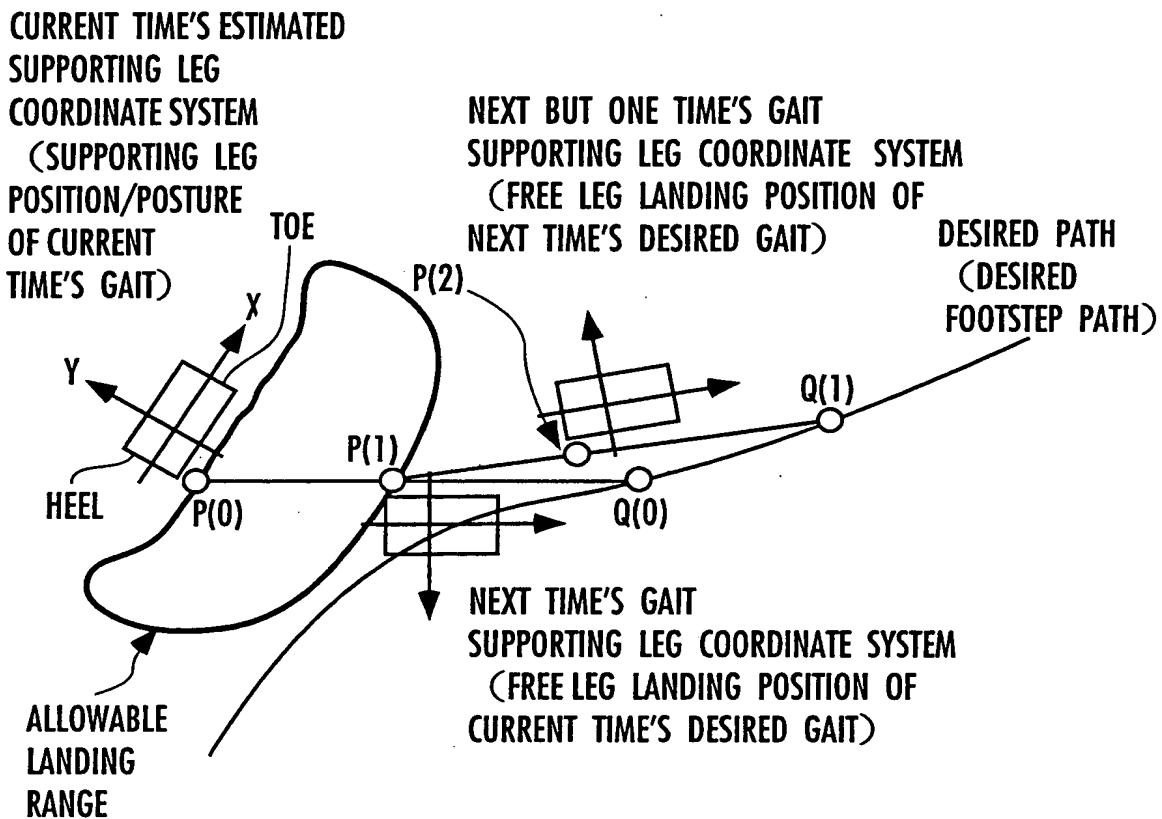
DETERMINE POSITION AND ORIENTATION OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM SO THAT POSITION OF REPRESENTATIVE POINT OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS P(2) AND DIRECTION OF X-AXIS OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS ORIENTATION OF LINE SEGMENT P(1)Q(1)

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FIG. 26



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## FIG. 27

ENTRY

S3500

DETERMINE DEVIATION  $e$  BY WHICH DESIRED ZMP EXCEEDS ALLOWABLE RANGE

S3502

$$P(1) = K_a * e + P(1)$$

S3504

DETERMINE POSITION AND ORIENTATION OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM SO THAT POSITION OF REPRESENTATIVE POINT OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS  $P(1)$  AND DIRECTION OF X-AXIS OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS ORIENTATION OF LINE SEGMENT  $P(0)Q(0)$

S3506

DETERMINE NEXT TIME'S SHORT-TERM DESIRED POINT  $Q(1)$  BASED ON REPRESENTATIVE POINT  $P(1)$  OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM AND DESIRED PATH

S3508

DETERMINE REPRESENTATIVE POINT  $P(2)$  OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM ON LINE SEGMENT  $P(1)Q(1)$  SO AS NOT TO EXCEED ALLOWABLE LANDING RANGE (SELF-DEPENDENT ALLOWABLE LANDING POSITION RANGE)

S3510

DETERMINE POSITION AND ORIENTATION OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM SO THAT POSITION OF REPRESENTATIVE POINT OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS  $P(2)$  AND DIRECTION OF X-AXIS OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM IS ORIENTATION OF LINE SEGMENT  $P(1)Q(1)$

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## FIG. 28

ENTRY

S3600

SET FIRST TURNING GAIT DETERMINED IN LAST CONTROL PERIOD AS CURRENT TIME'S GAIT, AND SECOND TURNING GAIT AS NEXT TIME'S GAIT

S3602

CALCULATE PREDICTED NEXT TIME'S LANDING POSITION/POSTURE AND PREDICTED NEXT BUT ONE TIME'S LANDING POSITION/POSTURE BASED ON ESTIMATED SUPPORTING LEG COORDINATE SYSTEM, AND CURRENT TIME'S DESIRED GAIT AND NEXT TIME'S DESIRED GAIT

S3604

CALCULATE PREDICTED NEXT TIME'S LANDING POSITION DEVIATION AND PREDICTED NEXT TIME'S LANDING ORIENTATION DEVIATION, WHICH ARE POSITIONAL DEVIATION AND ORIENTATIONAL DEVIATION FROM DESIRED PATH OF PREDICTED NEXT TIME'S LANDING POSITION/POSTURE

S3606

CALCULATE PREDICTED NEXT BUT ONE TIME'S LANDING POSITION DEVIATION AND PREDICTED NEXT BUT ONE TIME'S LANDING ORIENTATION DEVIATION, WHICH ARE POSITIONAL DEVIATION AND ORIENTATIONAL DEVIATION FROM PATH OF PREDICTED NEXT BUT ONE TIME'S LANDING POSITION/POSTURE

S3608

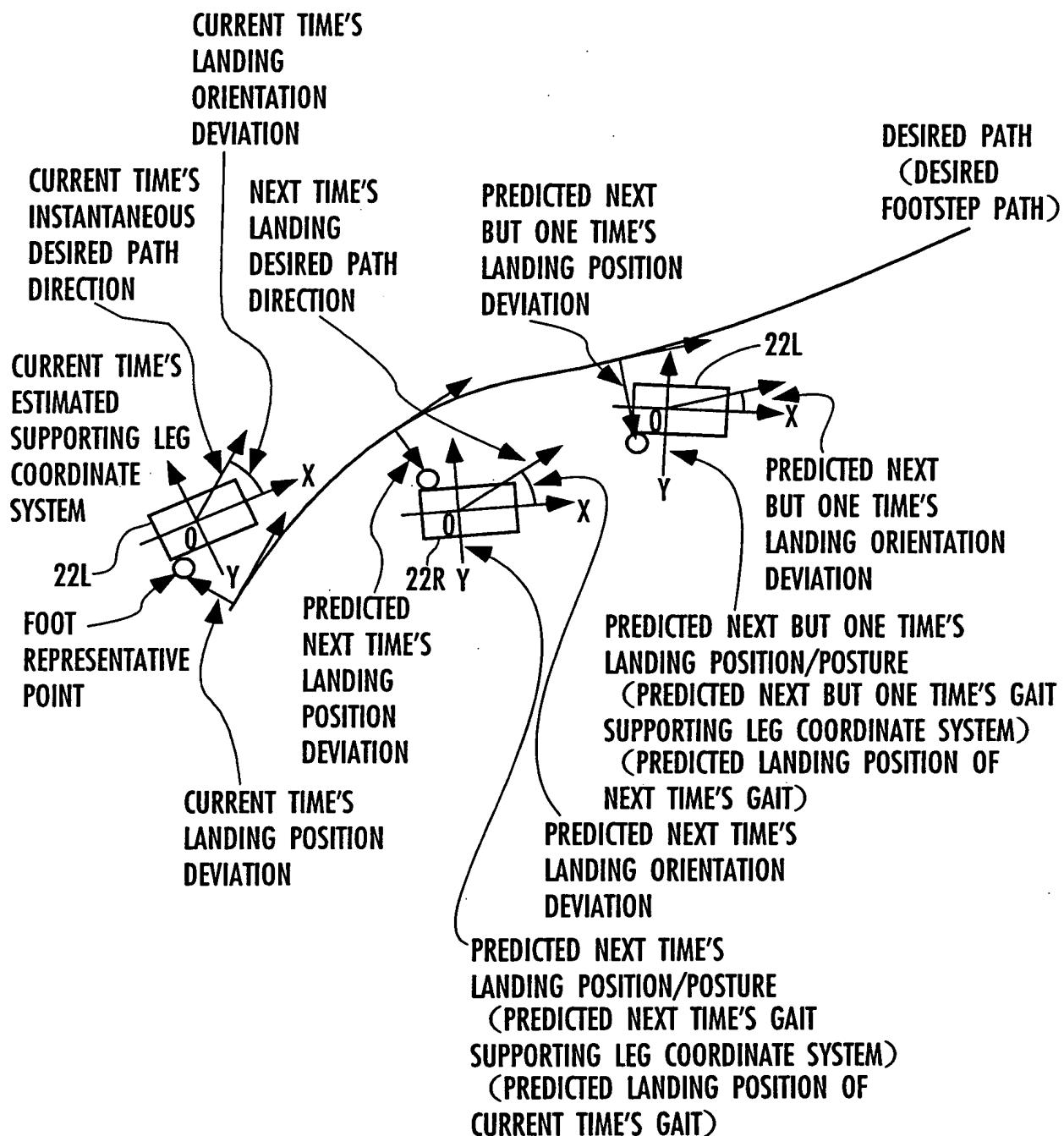
CORRECT POSITION AND ORIENTATION OF NEXT TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM AND POSITION AND ORIENTATION OF NEXT BUT ONE TIME'S GAIT SUPPORTING LEG COORDINATE SYSTEM BASED ON ABOVE DEVIATION

RETURN

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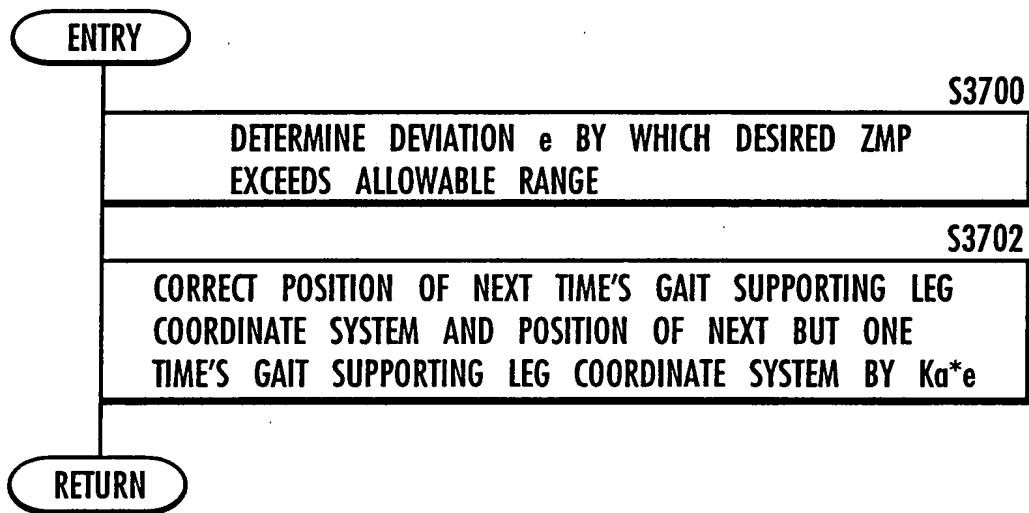
FIG. 29



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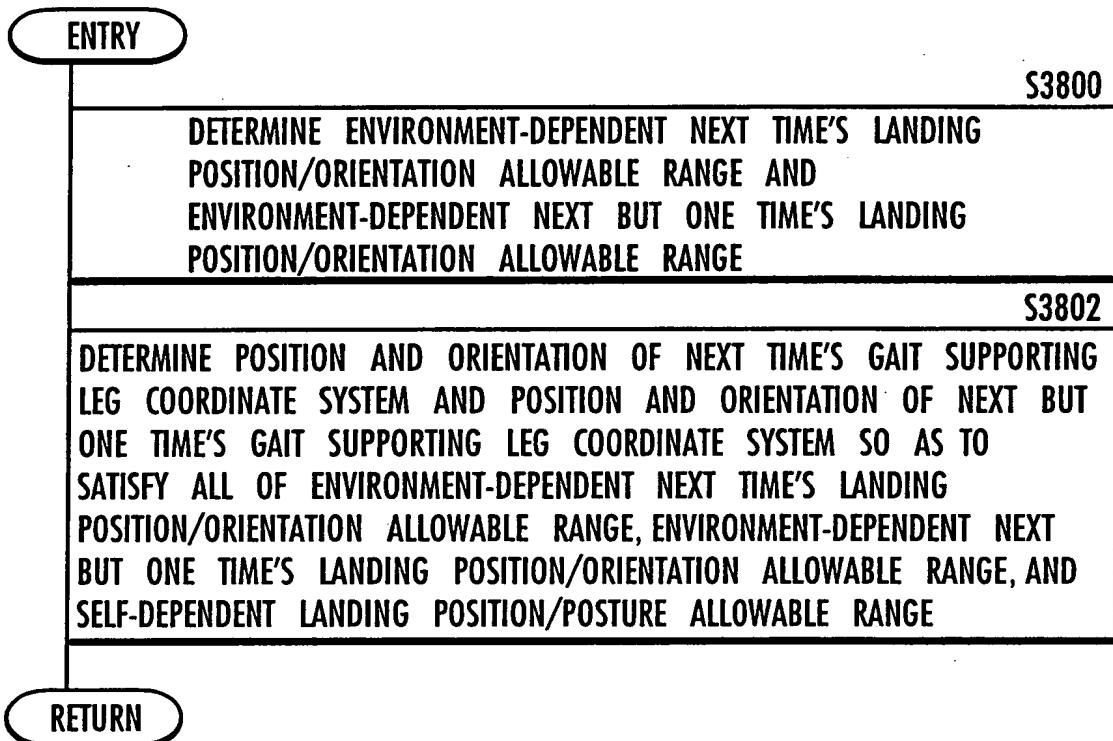
FIG. 30



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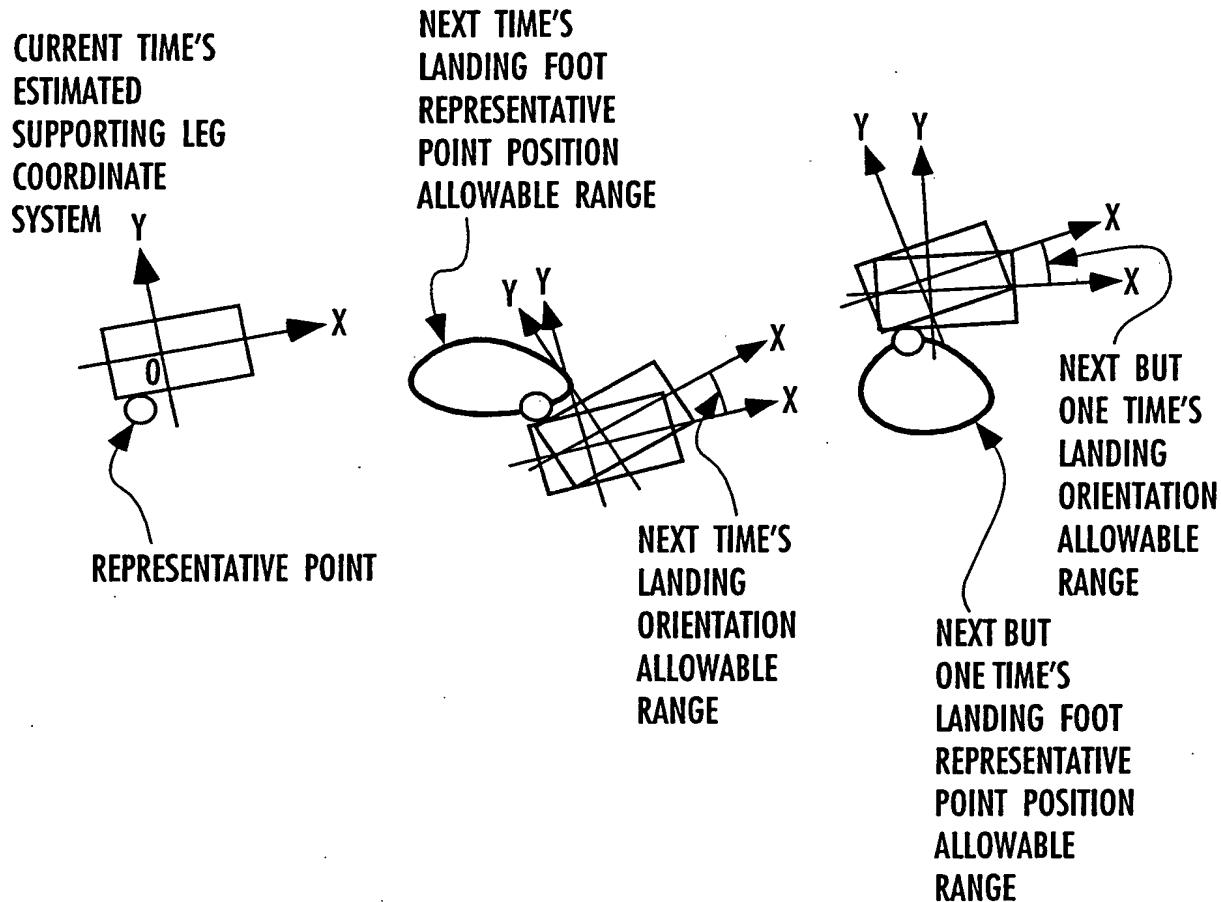
FIG. 31



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FIG. 32



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FIG. 33

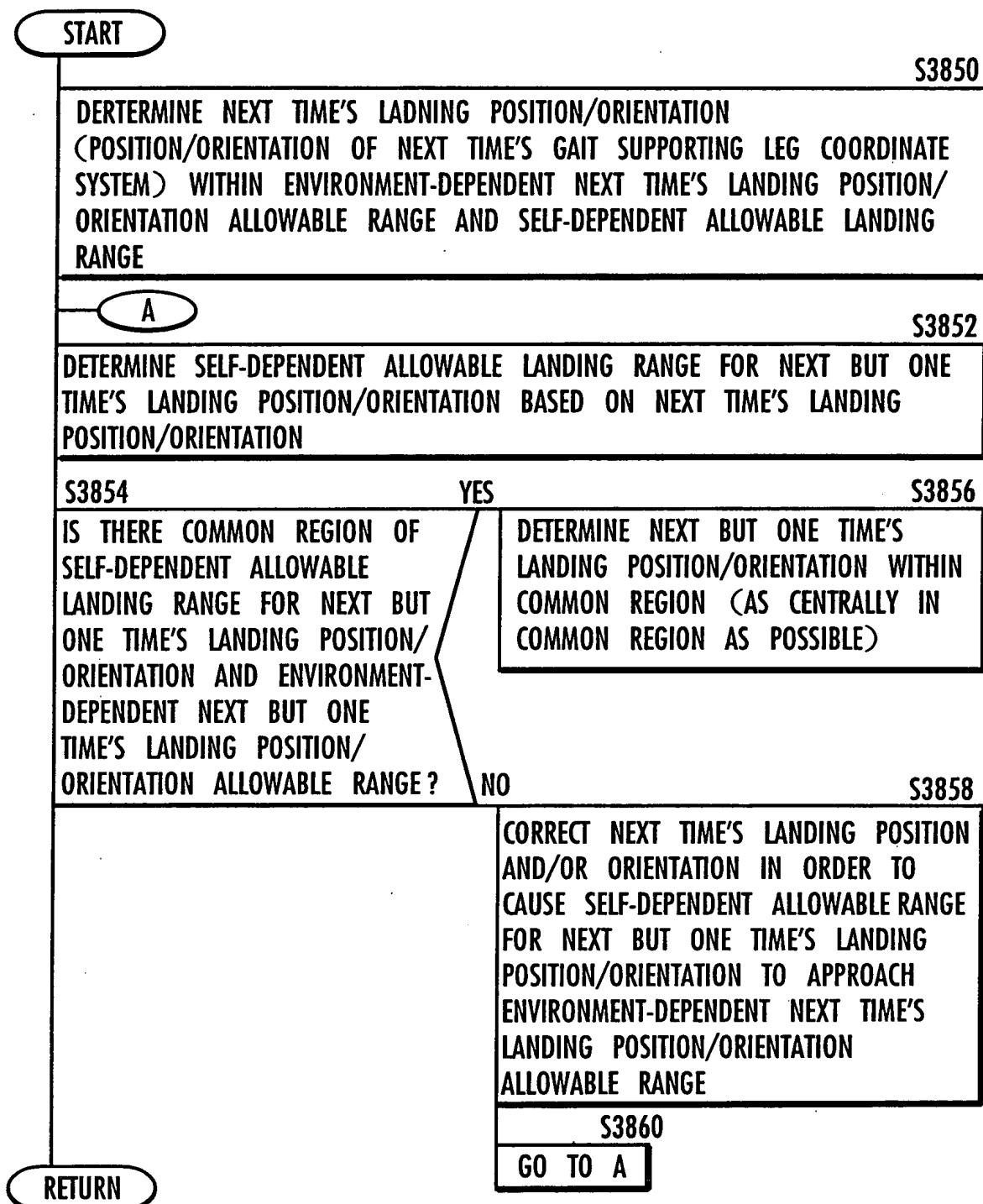
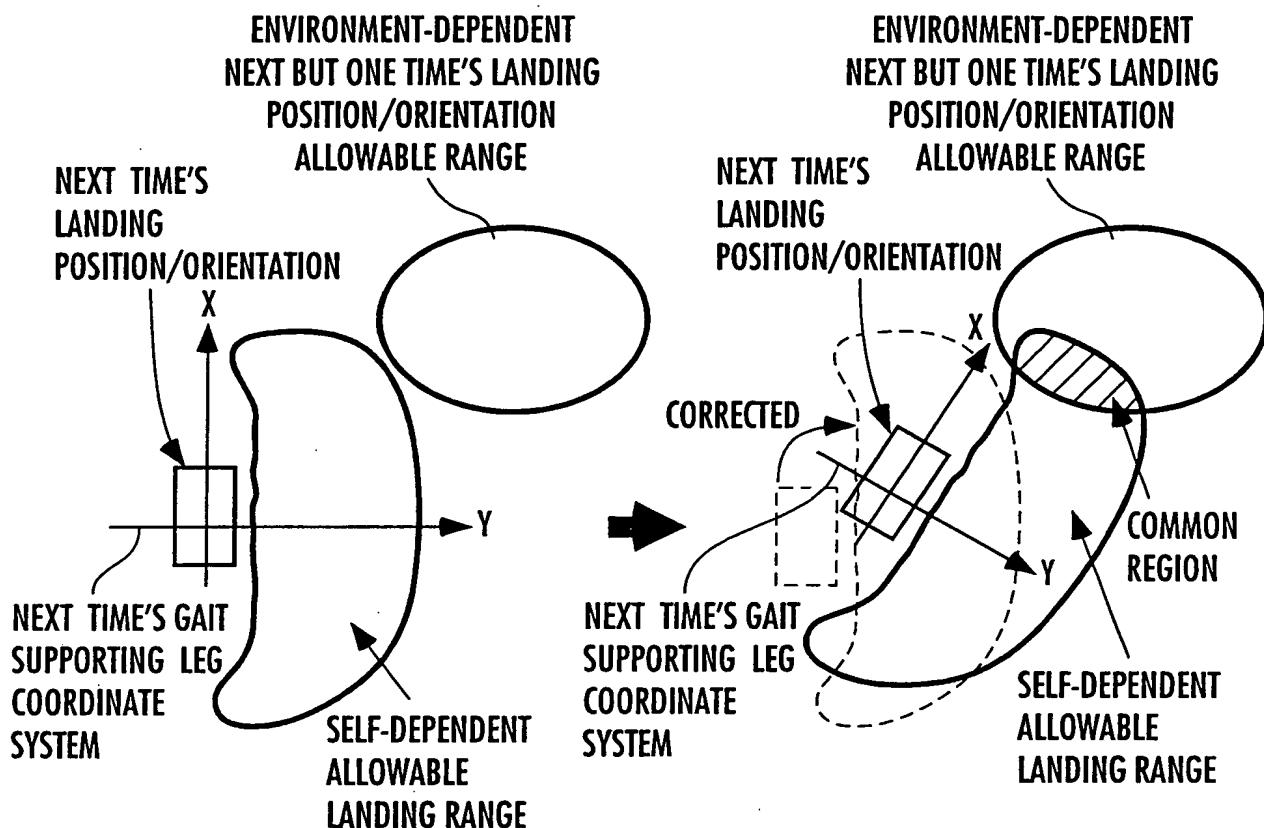


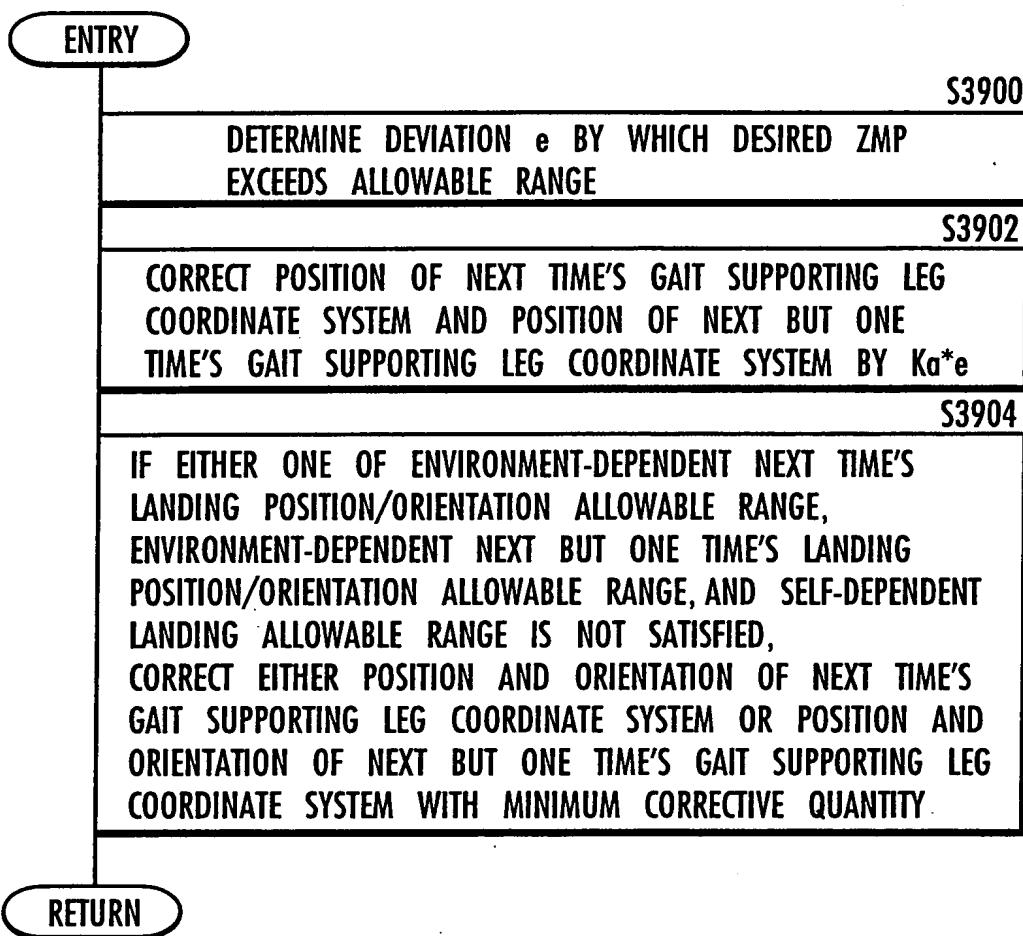
FIG. 34



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FIG. 35



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## FIG. 36

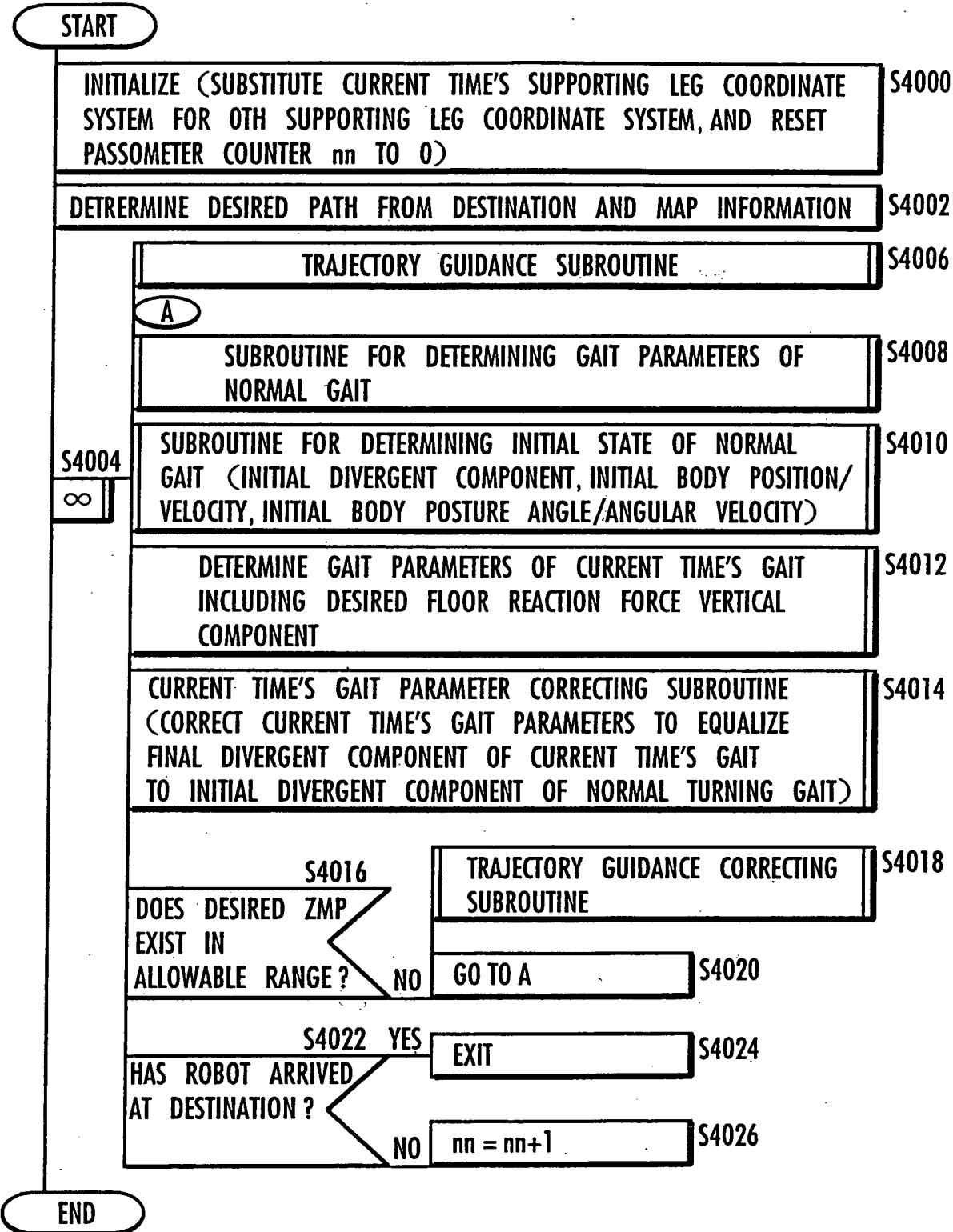


FIG. 37

